

# To what extent does uncertainty in the aerosol direct radiative forcing impact weather forecasts?

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# Aerosols in NWP models

- Aerosol perturb the atmospheric radiative heating rates, the surface energy balance and cloud radiative forcing. To what extent this matters for medium range global weather forecasting?
- Uncertain knowledge of emissions, composition and absorption characteristics
- Complexity of aerosol treatment in NWP: balance between time constraint, uncertainty in effects magnitude, aim of forecast.
- Advance in computer power and aerosol models allows now for a more systematic documentation of impact of aerosols (and uncertainties therein) on weather forecasts (e.g. Mulcahy et al. 2014, Colarco et al. 2014, Toll et al. 2016).

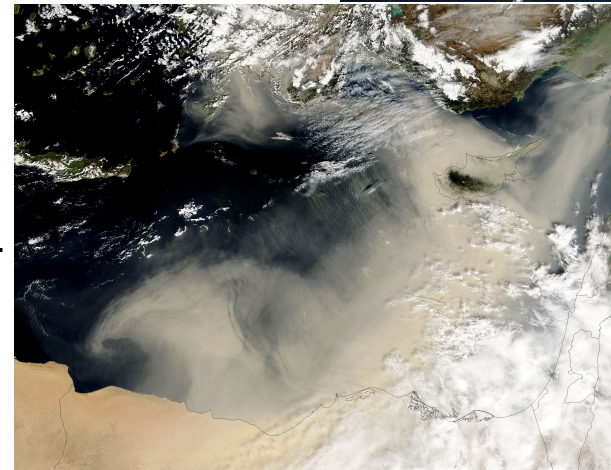
Smoke from Alaskan fires reaches Svalbard in July 2015 – Zeppelin station (c/o Per Erik Hanevold, NPI)



Pollution over Northern Italy, Feb 2005

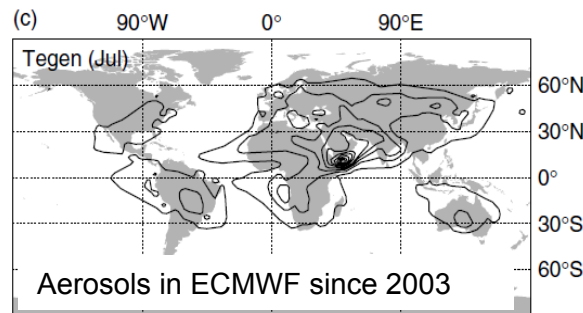
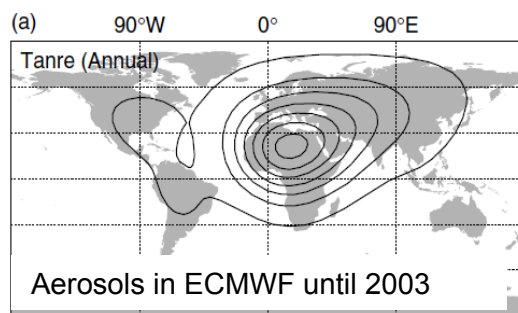


Dust storm over Eastern Mediterranean, Feb 2006



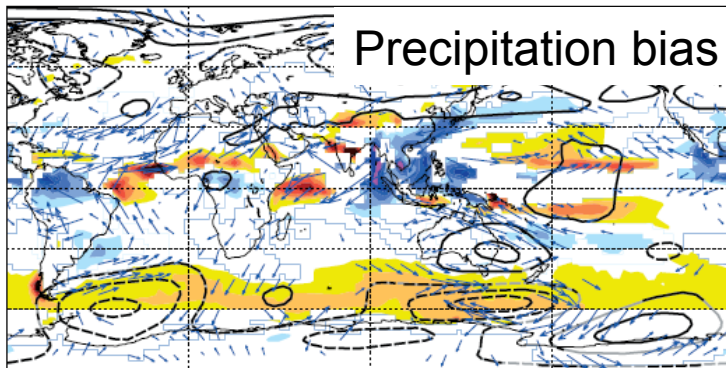
# Climatological aerosols and weather forecast skill

- Better representation in the seasonal distribution of aerosol (dust especially) affects the model mean state....
- ....changes in the mean state also improve the representation of variability in specific regions. + 1 day predictability gained in W. Africa monsoon region
- ....and via Rossby-wave forcing affects extratropical weather

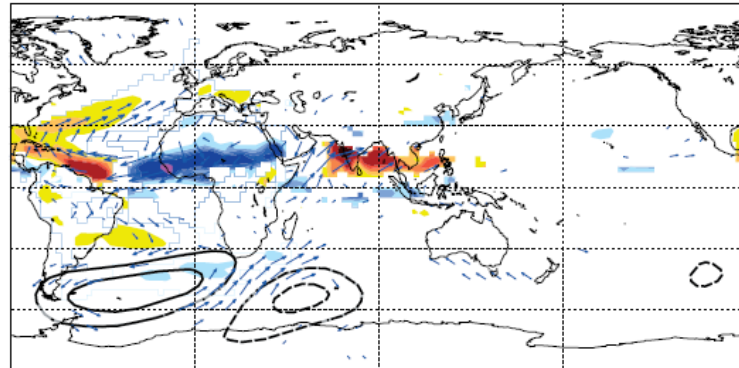
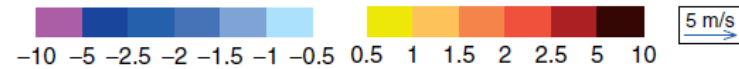


OLD: based on Tanre et al. 1984  
NEW: based on Tegen et al. 1997

(b) JJA OLD - OBS



(c) JJA NEW - OLD

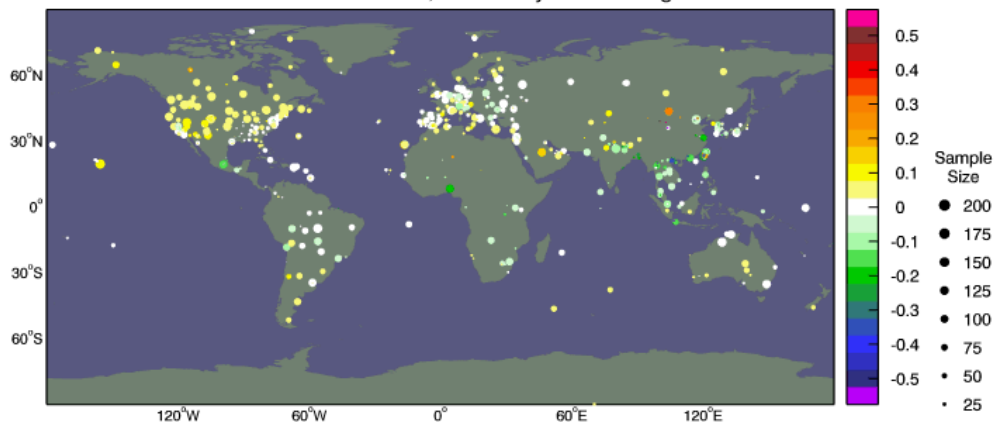


Rodwell and Jung, 2008

# CAMS aerosol model

(Flemming et al. 2016)

FC-OBS Bias. Model (camsira) AOT @ 550nm vs L2.0 Aeronet AOT @ 500nm.  
1 Jan 2003 - 23 Dec 2015. FC hrs: 06,18Z. 30-day means using T+3 to T+12



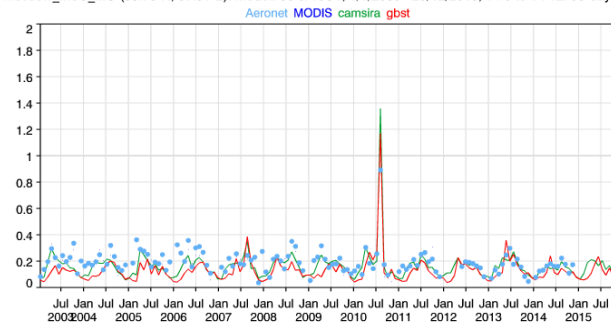
- CAMS (a.k.a. MACC/GEMS, Hollingsworth 2005) Aerosol-model developed in past 8 years:

- Bulk model ~10 tracers, ECMWF meteorology
- MODIS AOT assimilated
- Constrained surface emissions for fires and anthropogenic sources
- Highly under-constrained problem!
- CAMS-interim reanalysis 2003-2014

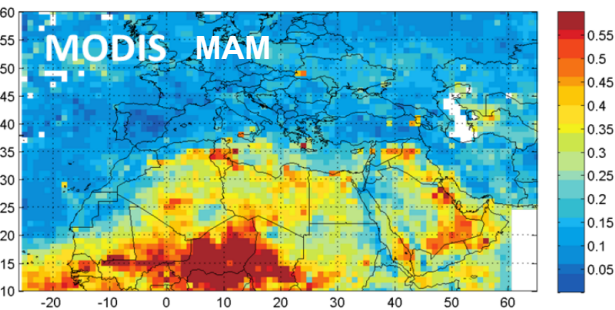
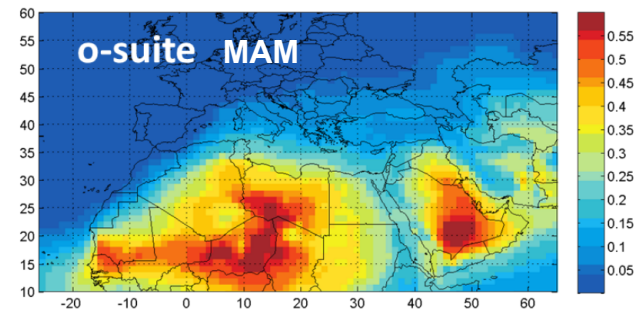
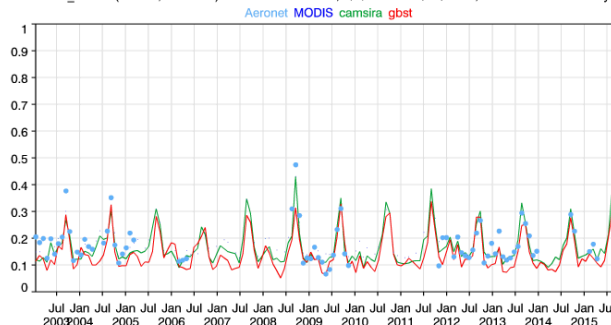


EUROPEAN CENTRE FOR MEDIUM-RANGE WEATH  
ERB Workshop 18-21 October 2016

Comparison of camsira & gbst and MODIS AOT at 550nm and L2.0 Aeronet AOT at 500nm over Moscow\_MSU\_MO (55.70°N, 37.51°E). Model: 06 & 18UT, 1/1/2003 - 23/12/2015, T+3 to T+12. 30-day means.

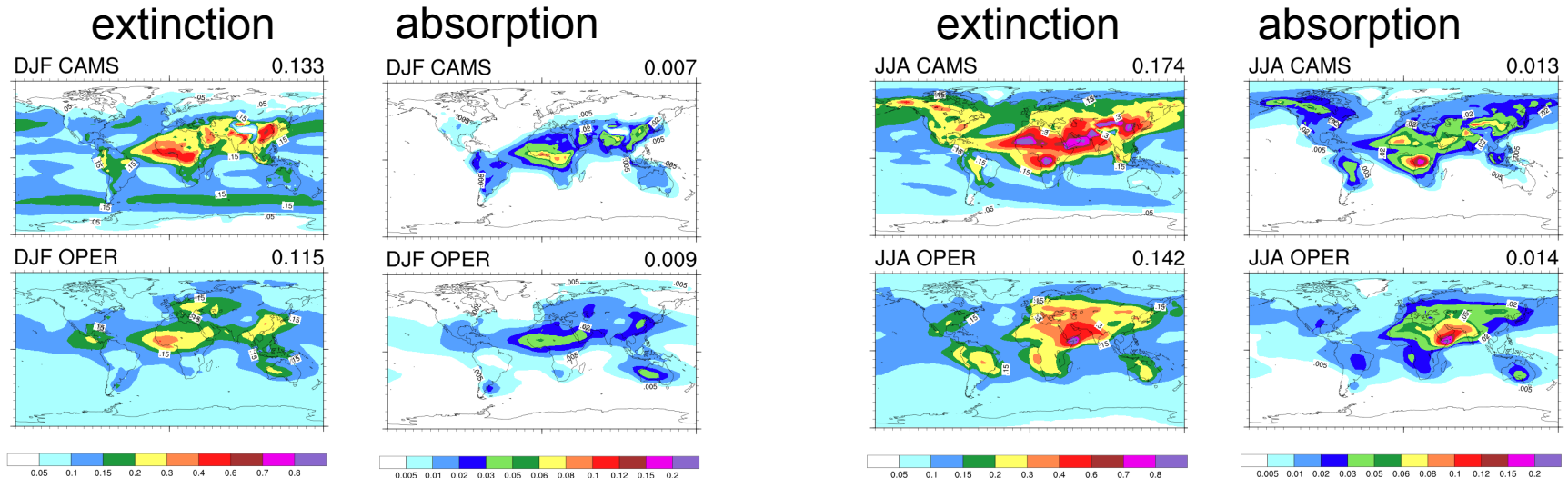


Comparison of camsira & gbst and MODIS AOT at 550nm and L2.0 Aeronet AOT at 500nm over Ascension\_Island (7.98°S, 14.41°W). Model: 06 & 18UT, 1/1/2003 - 23/12/2015, T+3 to T+12. 30-day means.



# Climatological AOD at 550 nm distribution

## CAMS vs operational climatology (based on Tegen et al. 1997)



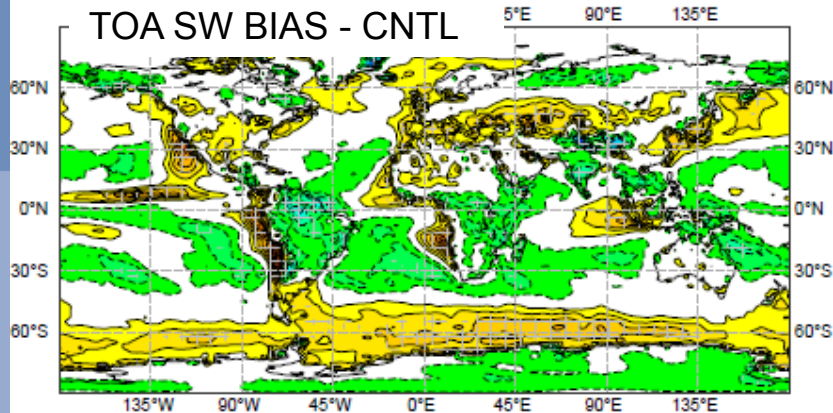
- Updated spectral radiative properties, RH dependent
- Three size bins for dust and sea salt
- Some highlights:
  - Larger Sea Salt radiative forcing ( $\sim 1 \text{ W/m}^2$  more reflection at TOA over oceans)
  - Changes in biomass burning seasonal cycle (up to  $20 \text{ W/m}^2$  difference in total SW absorption locally)
  - Changes in dust distribution, higher on Sahara and Taklamakan, lower on Indian Ocean and Australia, reduction in dust SW absorption
  - Anthropogenic emissions lower over Europe, higher over E Asia

# Impact on global TOA flux – 4 years uncoupled “climate” runs

- Impact the spatial variability of errors. Improvement in the RMSE on both LW and SW also through feedback with cloud fields.
- Small changes compared to errors in clouds radiative forcing!

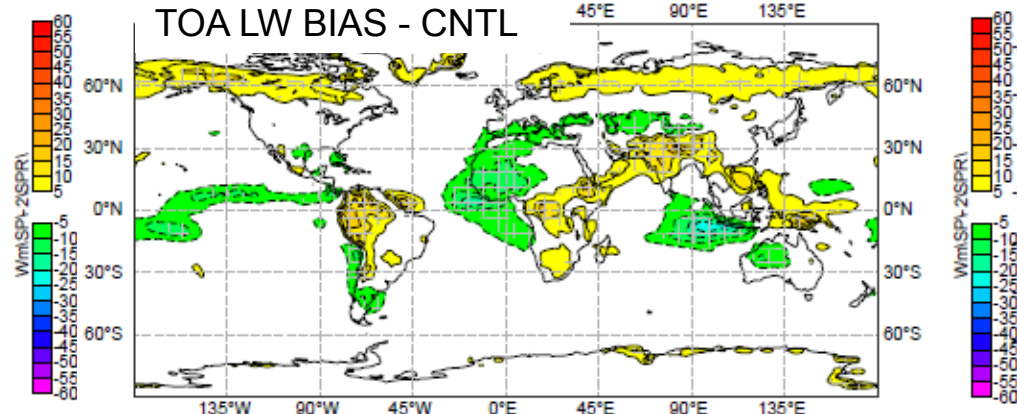
Difference gj1y - CERES-EBAF 50N-S Mean err -0.883 50N-S rms 8.96

TOA SW BIAS - CNTL



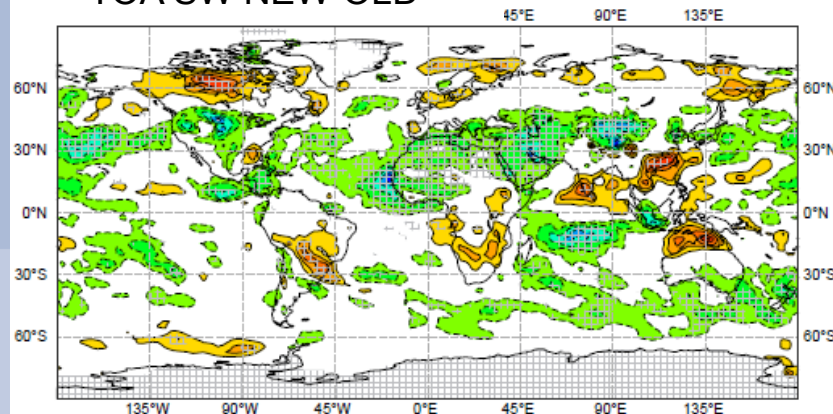
Difference gj1y - CERES-EBAF 50N-S Mean err -0.299 50N-S rms 5.13

TOA LW BIAS - CNTL



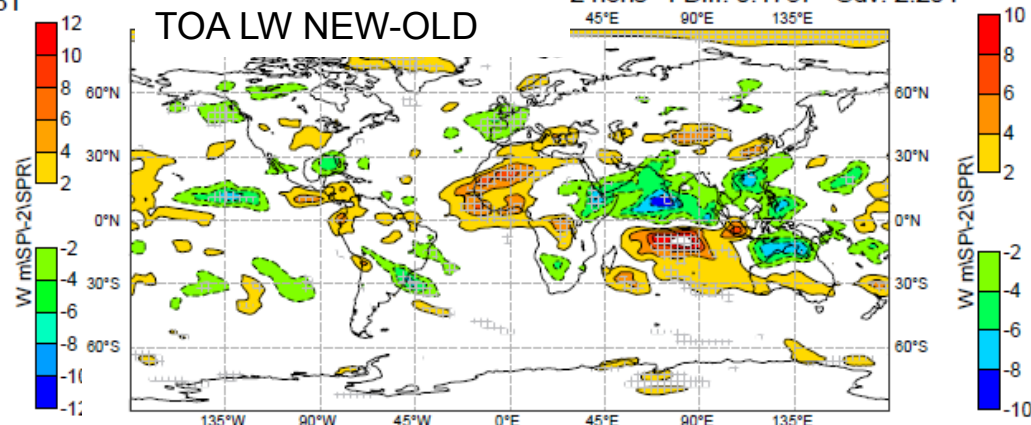
TOA SW NEW-OLD

nens=4 Diff: -0.8329 Sdv: 2.581



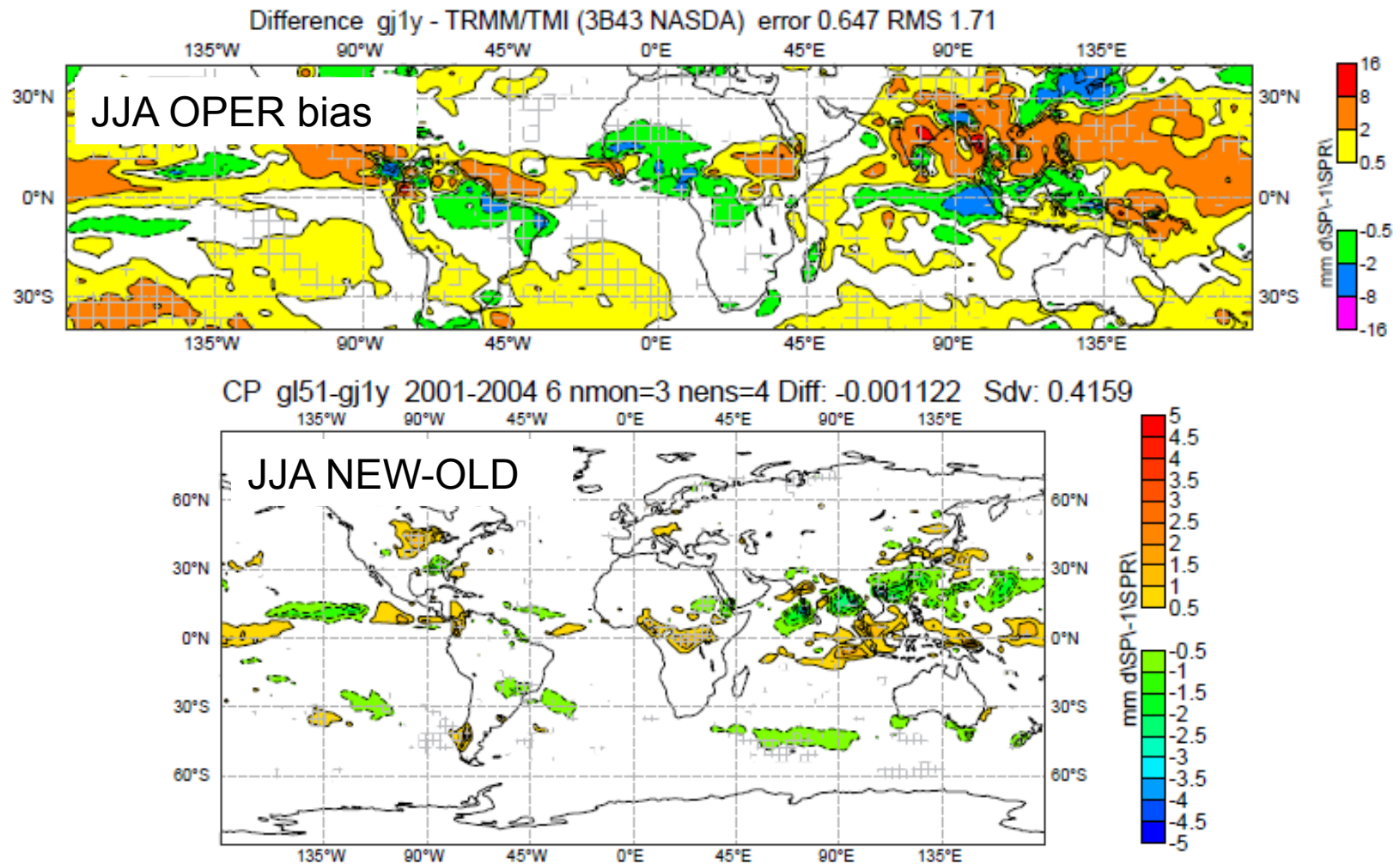
TRD 2151 214y 2000 2004 0 rms=12 nens=4 Diff: 0.1787 Sdv: 2.204

TOA LW NEW-OLD



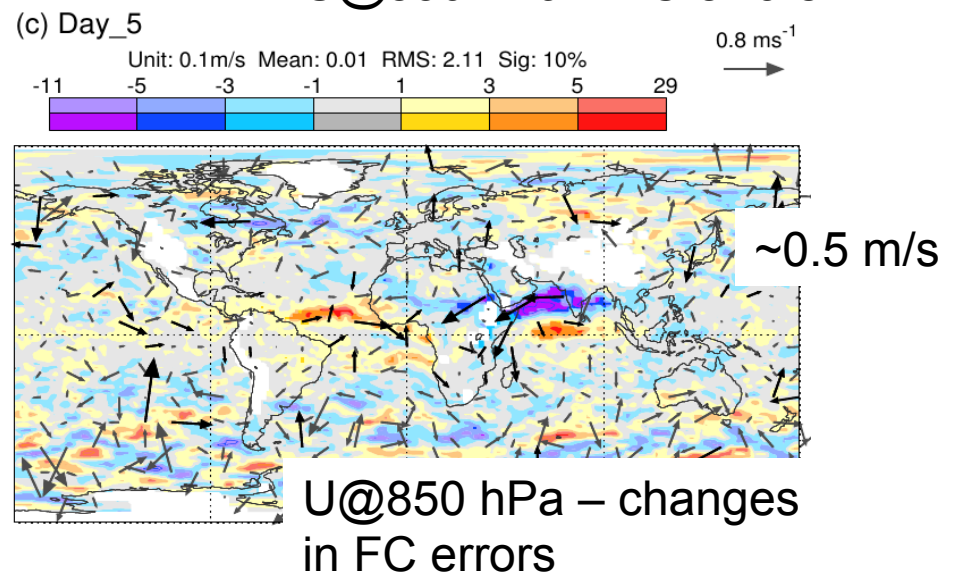
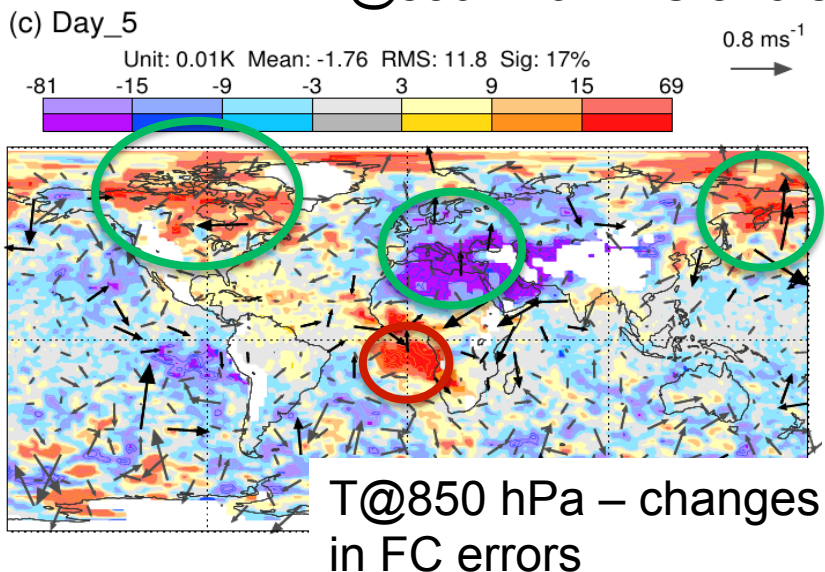
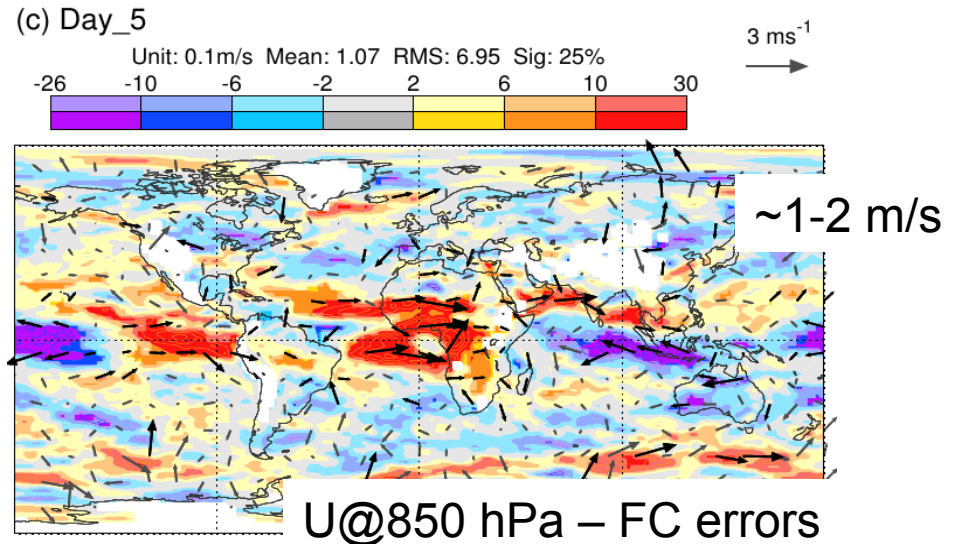
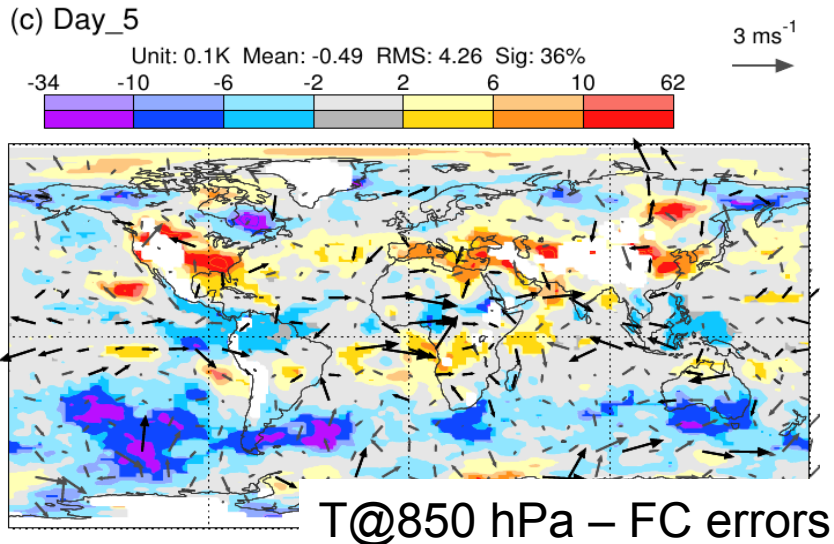
# Impact on global precipitation

Small impact, not as dramatic as for the change from and annual-mean climatology



# Forecast performance - 1

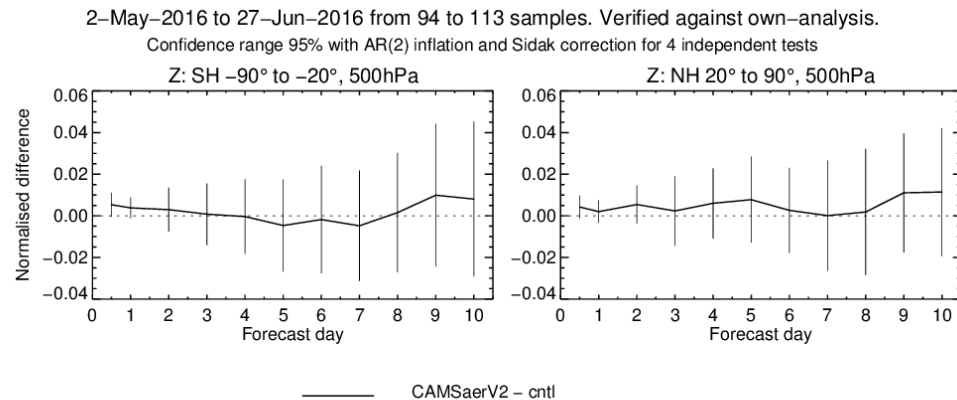
- Regional forecast errors reduced. Feedback with local circulations e.g. JJA Indian Monsoon



# Forecasts performance - 2

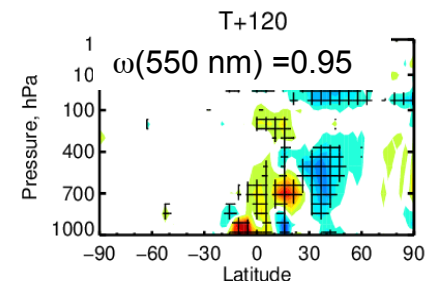
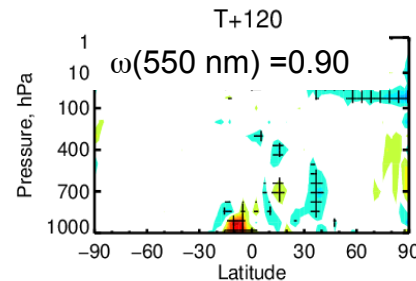
- Large scale headline skill scores: no impact in the flow variability, changes the mean state.

500 hPa geopotential height normalized rmse difference

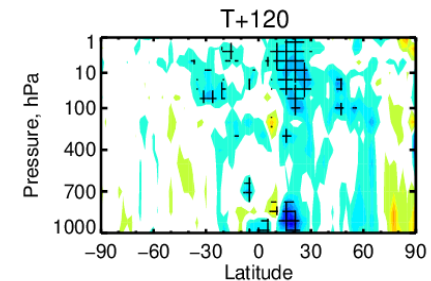
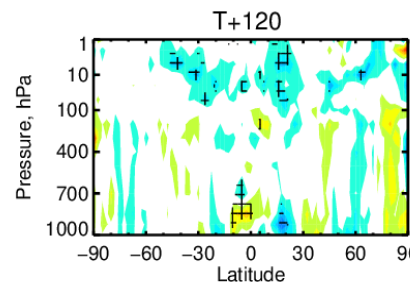


- Sensitivity to uncertainty in radiative properties, in particular dust absorption:

Temperature,  
normalized rmse  
difference - JJA

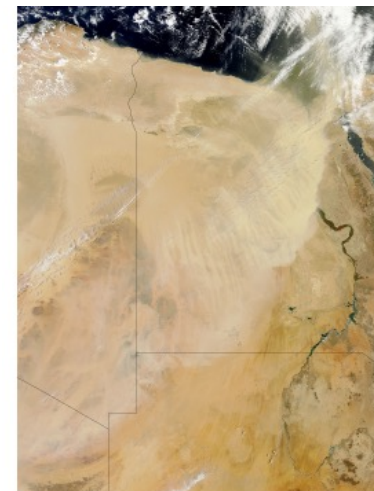


Wind,  
Normalized rmse  
difference - JJA



# Interactive prognostic aerosols

- Experiments suggest
  - Some impact on local surface parameters
  - Changes in boundary layer circulation can impact sources (for dust) and create feedback
  - Not yet clear whether these effects might be important on regional scale for long-range forecasts

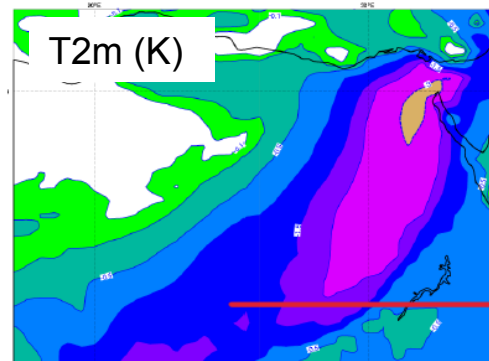


Egypt dust storm  
case, April 2012

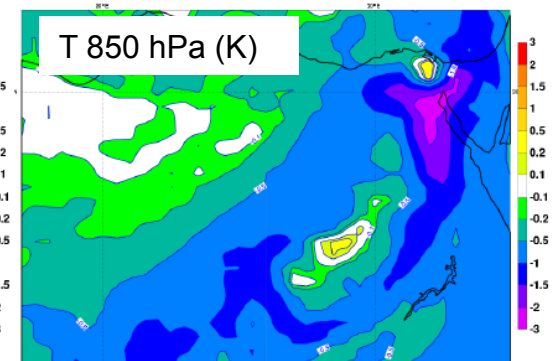
Interactive prognostic  
aerosols impact on  
boundary layer  
meteorology.

Feedback on aerosol  
sources  
(Remy et al. 2015)

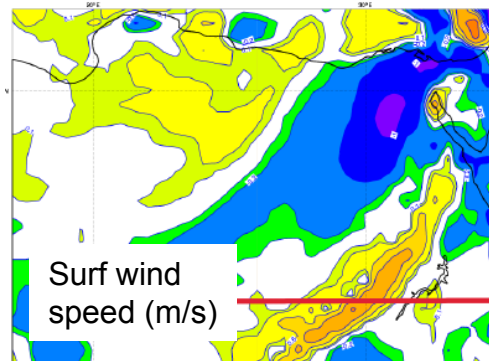
Tuesday 17 April 2012 00UTC MACC Forecast t+036 VT: Wednesday 18 April 2012 12UTC  
2m temperature (K) diff SW - REF



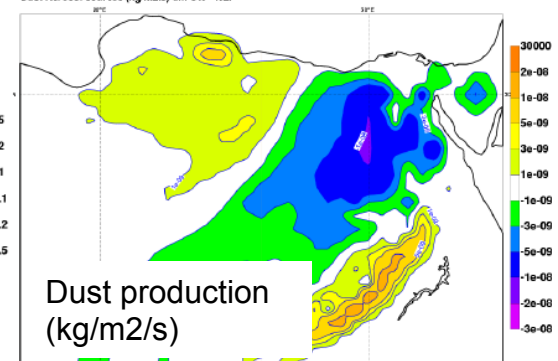
Tuesday 17 April 2012 00UTC MACC Forecast t+036 VT: Wednesday 18 April 2012 12UTC  
850 hPa temperature (K) diff SW - REF



Tuesday 17 April 2012 00UTC MACC Forecast t+036 VT: Wednesday 18 April 2012 12UTC  
Wind speed used for dust aerosol production (m/s) diff SW - REF



Tuesday 17 April 2012 00UTC MACC Forecast t+036 VT: Wednesday 18 April 2012 12UTC  
Dust Aerosol sources (kg/m2/s) diff SW - REF



## Concluding remarks

- Monthly-mean climatological distribution of aerosols radiative forcing captures most of the direct aerosol radiative forcing affecting synoptic-scale weather.
- Changes in aerosol direct radiative forcing affects mainly the mean model climate and radiative fluxes with negligible impact on the model variability and large-scale forecast skill scores.
- Uncertainty in aerosol distribution and radiative properties can have a significant impact on model biases affecting regional weather
- Interactive prognostic aerosols might improve AOT forecasts and the representation of surface weather for specific events, provided that the aerosol field is well represented (e.g. problems in fire emission)!
- In view of long-range forecasts interaction with fully coupled ocean-atmosphere system is being explored